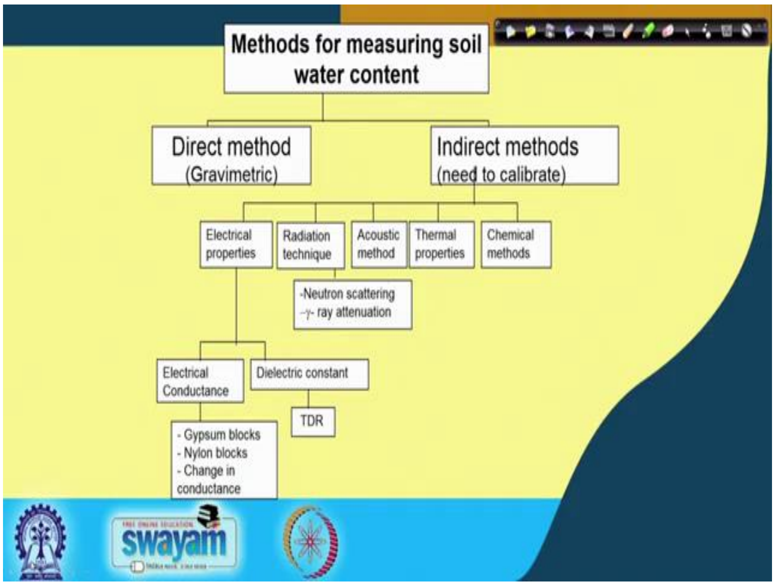
Soil Science and Technology
Prof. Somsubhra Chakraborty
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 15
Tutorial

Welcome friends to this lecture of Soil Science and Technology and in this lecture, we will start from the slide where we left yes in the last lecture.

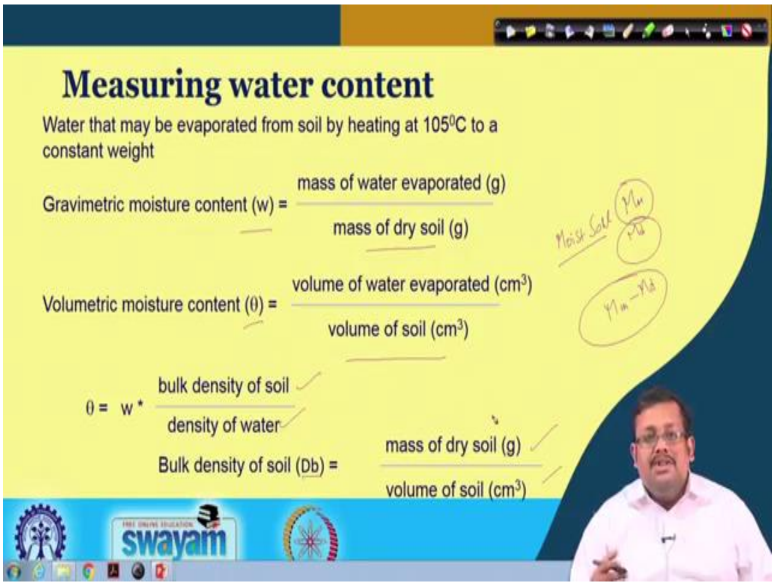
(Refer Slide Time: 00:25)



And in the last lecture we started about the methods of measuring the soil content and today, we will try to finish that and today this is the last lecture of week 2.

So, we will try to show you some numerical examples regarding the bulk density, particle density and soil water content and porosity which already I have covered. So, let us start with the methods of measuring soil water content. So, we have already covered this slide in our last lecture.

(Refer Slide Time: 01:07)



So, we should move from here and let me show you some measurement of water content.

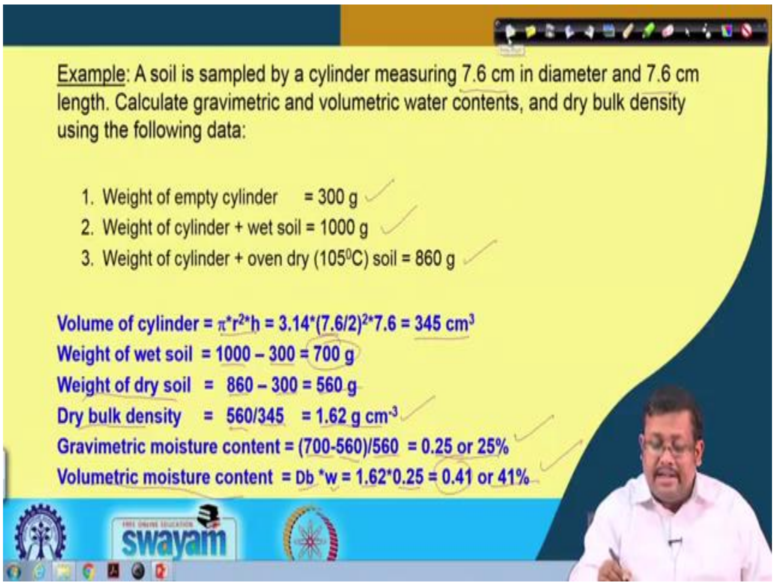
Measurement of water content, as you know the direct method is called gravimetric method. So, measuring water content can be done by this gravimetric method and water may be evaporated from soil by heating at the 105 degree centigrade to a constant weight. So, what happens we take some moist soil samples from the field and we dry that moist soil and we take the moist soil weight, let us see that let us assume that it is a mass of moist soil and then we dry the soil at 105 degree centigrade overnight and as a result the water evaporated and then we get there mass of dry soil.

So, gravimetric moisture content which is denoted by w can be expressed in terms of mass of water evaporated in gram over mass of dry soil. Now we already know the mass of dry soil that is M d and mass of water evaporated can be already can be calculated by M m minus M d. So, if we if we subtract the weight of a dry soil from the weight of a moist soil we will get the mass of water evaporated and this is one of the major methods of measuring water content.

However, there is another direct method we call it volumetric moisture content and volumetric moisture content is generally expressed in terms of theta. And volumetric moisture content is basically volume of water evaporated over the volume of soil. And the relationship between volumetric moisture content and gravimetric moisture content is theta equal to w which is the gravimetric moisture content multiplied by bulk density of a soil over density of water which is generally 1.

Now, bulk density of soil which is Db you know that mass of dry soil over volume of soil. So, it is basically the bulk volume of the soil. So, by using this formula we can convert from volumetric moisture content to gravimetric moisture content and vice versa. So, these 2 methods are direct method for measurement of water content. So, let us see one example.

(Refer Slide Time: 03:51)



So, if you see that a soil is sampled by a cylinder measuring 7.6 centimeter in diameter and 7.6 centimeter length, so calculate gravimetric and volumetric water contents and dry bulk density using the following data. Now you can see already it is will given that weight of that empty cylinder which we used for collecting the soil from the field is 300 grams and weight of cylinder plus wet soil is 1000 grams and weight of cylinder plus oven weight which is 100 after drawing 100 you know over dry weight that is after drying at 105 degree centigrade, we get 860 grams.

So, let us you know solve this. So, we already know that the volume of this cylinder can be calculated by pi r square is the formula where we already know the value of r that is 7.6 and so using that we can you know we calculate these 345 cubic centimeter or cc. Now we know that weight of the weT soil is weight of the weight soil is basically the weight of the cylinder plus weT soil minus weight of the empty cylinder, so that will be

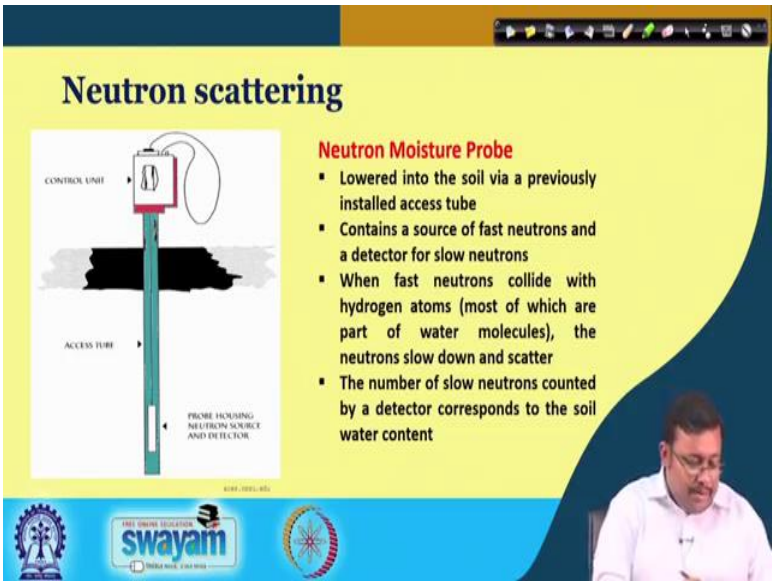
700 grams and we know and the weight of the dry soil is 860 grams we know minus 300 grams which is the weight of the empty cylinder.

So, we get 560 grams. So, dry bulk density is basically we are getting weight of the dry soil over the volume of the cylinder. Now volume of the cylinder is 345 and it is you know ultimately we are getting 1.62 gram per cc. Now gravimetric, so once we collect the ones we calculated this dry bulk density, now we can calculate this gravimetric moisture content. Now gravimetric moisture content you know, the weight of a moist soil minus weight of a dry soil over the weight of a dry soil.

So, we are getting 25 percent and also volumetric moisture content for calculating the volumetric moisture content you know we have to multiply the gravimetric moisture content with the dry bulk density. So, we already calculated the dry bulk density as 1.62 and we are multiplying it with 0.25, but 25 percent of gravimetric moisture content we are getting 0.41 or 41 percent.

So, this is the result. So, you know ultimately we calculated both gravimetric as well as volumetric moisture content. So, I hope that you have understood this solution. So, let us move ahead and see what are the other aspects of measurement of soil moisture?

(Refer Slide Time: 07:06)



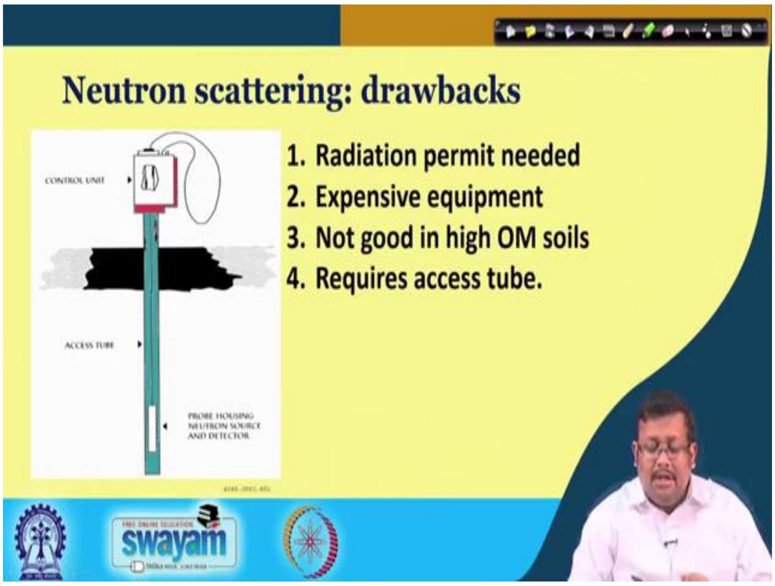
Now as I have already told you that in the indirect methods this neutron moisture probe or neutron scattering is very much important. Now there are some radiation methods if you if you go back to our previous slides, you can see that the radiation technique, there are 2 types of radiation techniques we generally use 1 is neutral scattering another is gamma ray attenuation.

So, let us talk about the neutron probe, we call it neutron moisture probe also. So, this is the picture of neutral moisture probe and basically in the neutral moisture probe, the probe is basically lowered. So, this is the soil surface and we generally lower the, we generally lower the probe. Now before lowering the probe we have to install this access pipe. Now this access tube is basically made of some metal and basically these neutron moisture probe is lowered into a soil where previously installed access tube.

And it contains the source of fast neutrons and a detector of slow neutrons. So, this is the, this probe contains a source of fast neutron as well as is detector of slow neutron. Now once we insert this probe into the soil through this access tubes and generate the neutrons these neutrons we will collide with the hydrogen atom. Now how these hydrogen atoms generated these hydrogen atoms are can are basically coming from the nearby water molecules. So, once these neutrons are you know neutrons collide with these hydrogen atoms of the water molecules the neutrons further slow down and scatter and we call it thermalized neutrons.

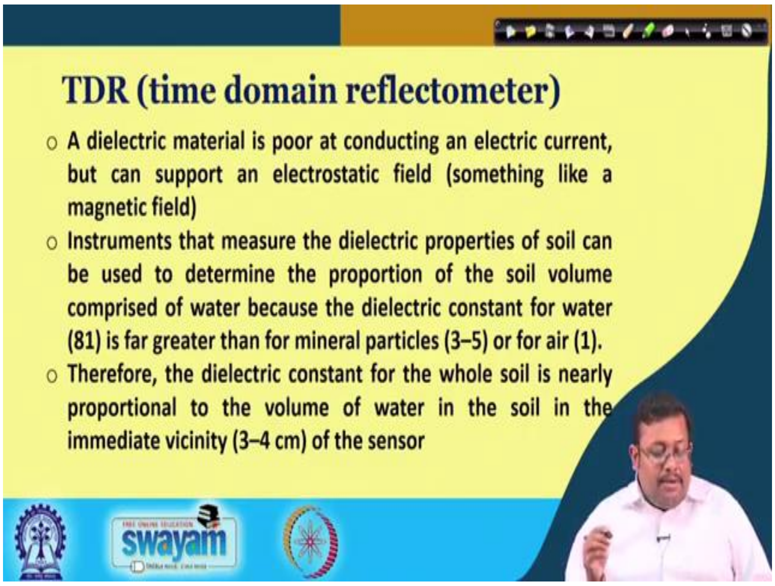
The slow neutrons are called thermalized neutrons and the number of slow neutrons or thermalized neutrons counted by a detector which is also present in this probe and this basically corresponds to the soil water content and by this you can calculate the soil moisture or soil water content. So, this is the principle or this is the working principle of this neutron moisture probe. So, let us see what are the, you know this is a very efficient method, but it has got some drawbacks also. So, let us see what the drawbacks of neutron moisture probe are.

(Refer Slide Time: 09:27)



First of all for operating neutron moisture probe, you need a radiation permit. Secondly, it is very much expensive instrument and thirdly it cannot be used in a high organic matter or organic matter with soil and finally, it requires at access tube. So, obviously, you can see there is a although the probe housing contains all the neutron generators and detectors, however you have to pre install a access tube and these access tube will be required for measurement of moisture content through these neutron moisture probe.

(Refer Slide Time: 10:09)



The another method is called TDR or type domain reflectometer. The time domain reflectometer works of the principle of time domain reflectometry. Now you know that a dielectric material is poor at conducting electrical current; however, it can support an electrostatic field something like a magnetic field and instruments basically the time domain reflectometer which you know which operates the principle of time domain reflectometery.

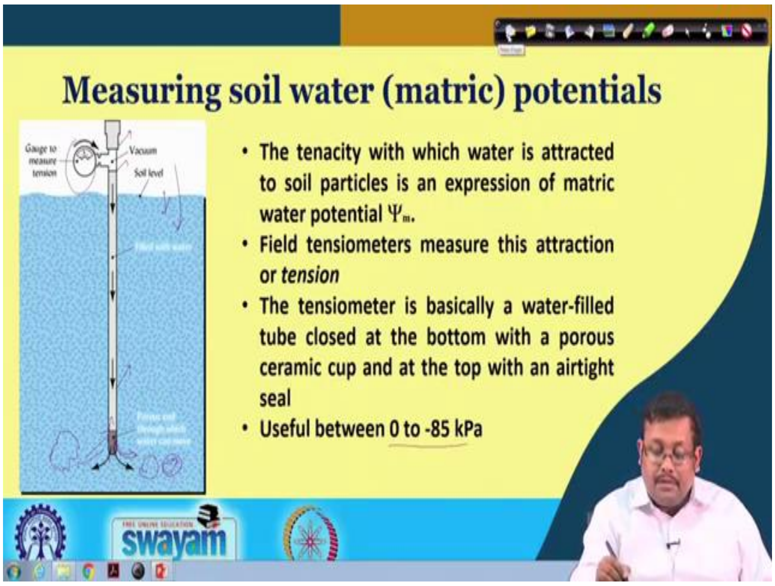
It can measure the dielectric properties of soil which can be used to determine the proportion of the soil volume comprised of water because, because of the fact that dielectric constant of water which is basically 18 is far greater than other mineral particles or for a generally in case of mineral particles, the dielectric constant varies from 3 to 5 and in case of airthe dielectric constant is 1.

So, you can see the dielectric constant in case of water is far greater and therefore, the dielectric constant for the whole soil is nearly proportional to the volume of water in the soil in the immediate vicinity that is 3 to 4 centimeter of the sensor. So, using this working principle this TDR basically works and it can basically measures the, you know moisture through it is dielectric constant. There is a stark difference of dielectric constant between soil moisture and other particles and air.

(Refer Slide Time: 11:40)

So, you can see these are the pictures of time domain reflectometer. Remember that these time domain reflectometer measures both soil moisture content and salinity. So, this is very important to remember.

(Refer Slide Time: 11:56)



And another important instrument for measuring the soil water or I would say matric potential. So, it is called tensiometer or field tensiometers.

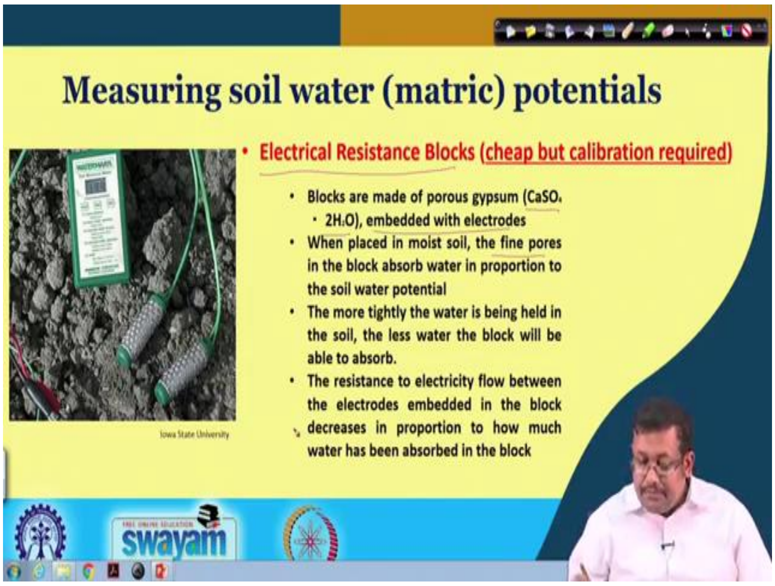
Now, you can see this is the field tensiometer and what happens? It is basically a water filled tube and water filled tube closed at the bottom with a porous cup, so this is a porous cup and at the top is a tight seal. So, there is a tight seal you can see and the tenacity with which the water is attracted to the soil particle is an expression of soil matric potential you already know that and remember that these tensiometer measures these attraction or tension.

So, soil or field or field tensiometer basically measure the soil water tension. What is the working principle of this tensiometer? Well, as you know it contains this porous cup, so once we insert this tensiometer into the soil, so based on the matric at potential of soil particles or based on the matric potential or attraction of water by soil matrix; obviously, the water will go away through this water we will release through these porous cup.

And as a result of water movement through this porous cup to the soil, the vacuum there will be a vacuum created at the top of the tensiometer. And this vacuum or air pressure or the tension in other words will be measured by a gauge which is fitted at the top of this tensiometer vice versa when there is a water movement, when they when we are apply the irrigation water, the excess of water we will further move towards the porous cup and it will it will it will it will go inside the tensiometer through this porous cup and as a result further, the vacuum will be adjusted or the you know and the vacuum will be further measured by this gauge.

So, this is the working principle of this field tensiometer. Remember that the field tensiometer basically works at you know potential range between 0 to minus 85 kilo Pascal. So, beyond 85 kilo Pascal of potential or tension these you know field tensiometer does not work properly. So, we have finished the field tensiometer let us see what else.

(Refer Slide Time: 14:59)

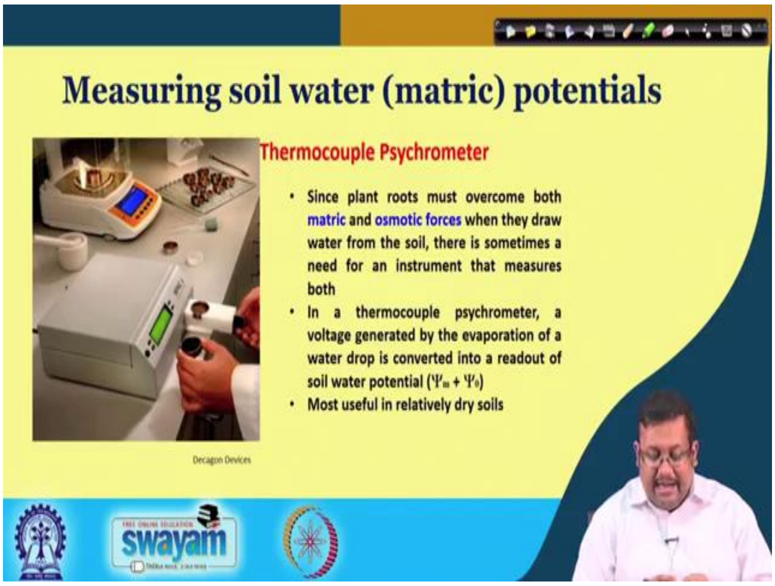


So, there is another important instrument we call it gypsum block. A gypsum block basically of you know of you know operates.

We also the, we will also termed the gypsum block as electrical resistant block because it is made up gypsum we call it gypsum block also. So, these you know these electrical resistant blocks are made of a porous gypsum you know the formula of gypsum CaSo 4 2H2O which is embedded with electrode and where we place these gypsum block into the moist soil the fine pores in the block absorb the water in proportion to the soil water potential. As the more tightly the water is absorbed by the soil matrix, the less likely that water will be absorbed by these probes.

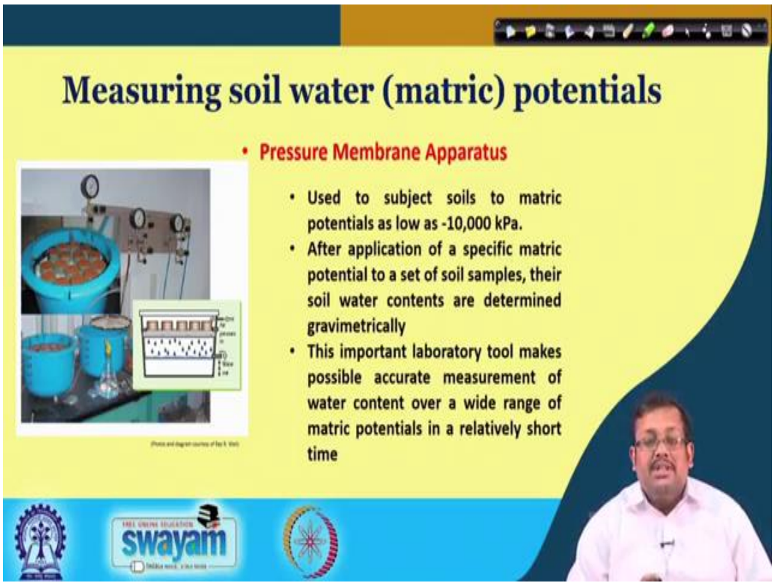
And as a result or another words the more tightly the water is absorbed by the soil matrics, less likely it will be you know it will be absorbed by the block. So, as a result the resistant or to electricity flow between the electric below between the embedded electrodes in the block decreases because of the changes in the water absorption and these changes in electricity flow is basically measured by this electrical resistant block and this is how it works. So, we have covered this.

(Refer Slide Time: 16:38)



Another important is thermocouple psychrometer. Now thermocouple psychrometer remember that these a picture of thermocouple psychrometer and thermocouple psychrometer works you know, it basically you know measures both matric and osmotic forces So, in a thermocouple psychrometer a voltage generated by the evaporation of a water drop is converted into a readout of soil water potential which is basically the combination of both matric potential and osmotic potential and it is most useful in relatively dry soils.

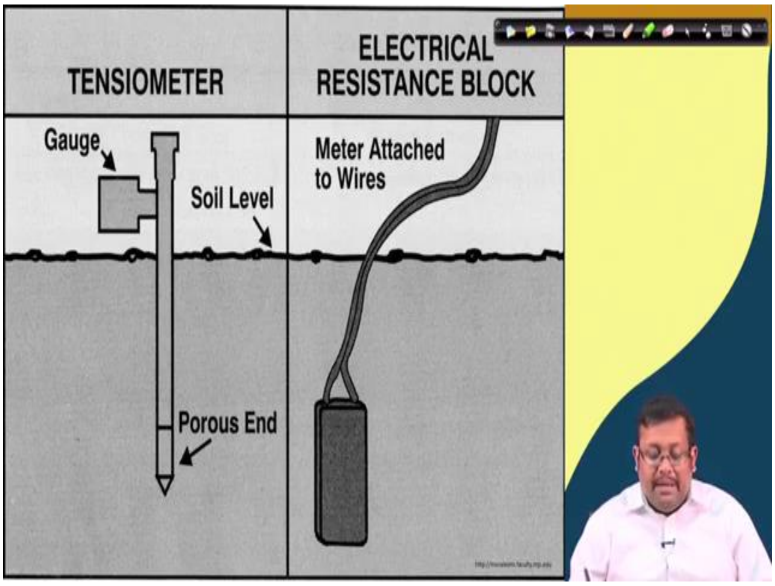
(Refer Slide Time: 17:14)



Another important you know apparatus is called pressure membrane apparatus. Now the pressure membrane apparatus is basically used to measure the water content at matric potential which is as low as minus 10000 kilo Pascal. So, up to this range you know tensiometer cannot read tensiometer is useful only up to minus 85 kilo Pascal; however, if you want to measure the soil water you content at minus 10000 as low as the, you know a tension a potential as low as minus 10000 kilo Pascal, you have to use these pressure membrane apparatus.

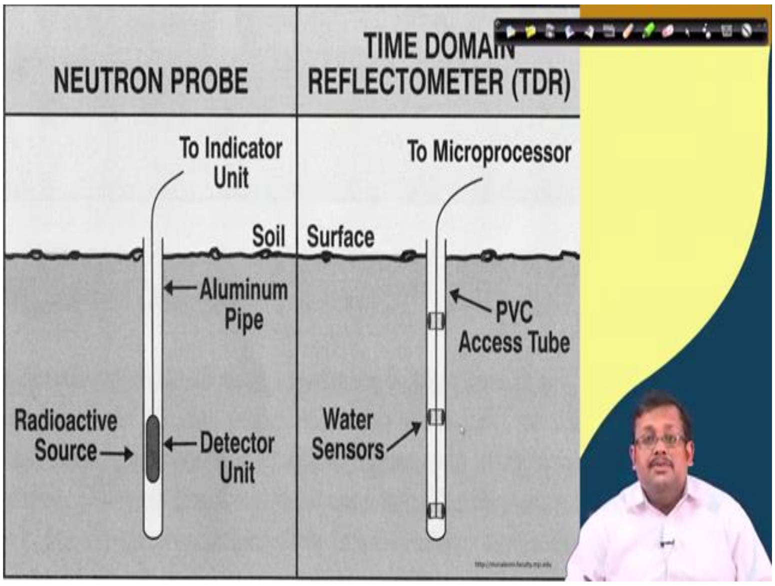
At this pressure membrane apparatus it basically after application of specific matric potential to a set of soil samples their soil water content and determined gravimetrically by this pressure membrane apparatus and this is a very important laboratory tool and it measure it makes possible accurate measurement of water content over a wide range of matric potential in a relatively short time.

(Refer Slide Time: 18:20)



So, this is in a nutshell you can see the tensiometer, how these porous end is inserted into the soil and the gauge basically measures the vacuum and electrical resistance block where the meter is attached to the wires, which measures the electrical flow resistant to electrical flow based on the about the moisture which is absorbed.

(Refer Slide Time: 18:41)



And this is neutron probe; we have already told that this is aluminium. You can see this is the aluminium access pipe and the, you know detector unit is inserted at the radioactive source is there and similarly time domain reflectometer or TDR, you can see there are water sensors and there is a PVC access tube.

So, this is a nutshell gives you know a basic idea about the different methods of soil water content.

(Refer Slide Time: 19:06)

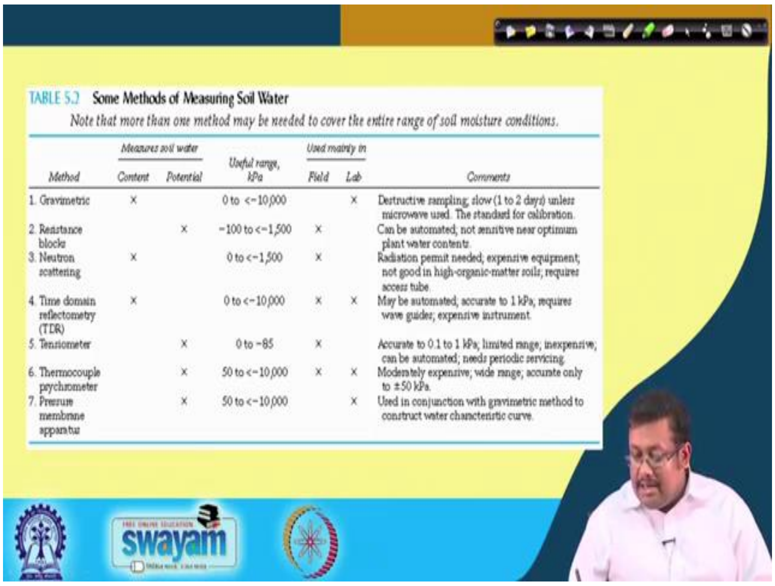


TABLE 5.2 Some Methods of Measuring Soil Water

Note that more than one method may be needed to cover the entire range of soil moisture conditions.

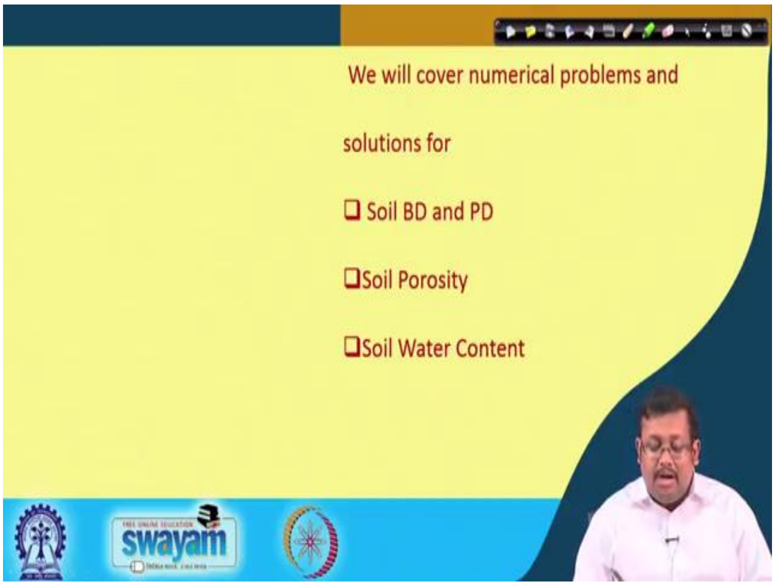
Method	Measures soil water: Content	Measures soil water: Potential	Useful range, kPa	Used mainly in: Field	Used mainly in: Lab	Comments
1. Gravimetric	×		0 to <−10,000		×	Destructive sampling; slow (1 to 2 days) unless microwave used. The standard for calibration.
2. Resistance blocks		×	−100 to <−1,500	×		Can be automated; not sensitive near optimum plant water contents.
3. Neutron scattering	×		0 to <−1,500	×		Radiation permit needed; expensive equipment; not good in high-organic-matter soils; requires access tube.
4. Time domain reflectometry (TDR)	×		0 to <−10,000	×	×	May be automated; accurate to 1 kPa; requires wave guides; expensive instrument.
5. Tensiometer		×	0 to −85	×		Accurate to 0.1 to 1 kPa; limited range; inexpensive; can be automated; needs periodic servicing.
6. Thermocouple psychrometer		×	50 to <−10,000	×	×	Moderately expensive; wide range; accurate only to ±50 kPa.
7. Pressure membrane apparatus		×	50 to <−10,000		×	Used in conjunction with gravimetric method to construct water characteristic curve.

And this slide shows a different pros and cons of you know different methods; obviously, these gravimetric method is a destructive method of measurement of water content and you know resistant block or gypsum block can be automated, but not sensitive to optimum blend water contains. So, these are some positive or negative attributes, such as tensiometer in case of tensiometer as you can see it is only accurate from 0.1 to 1 kilo Pascal as it is a limited range.

However pressure membrane apparatus you know it can be used for 50 to minus 10000 kilo Pascal and it is used in conjunction with diametric method to constant water characteristic curve. So, these are some characteristics of these different methods of water before a methods of measurement of water content and you can see which methods are used in the field and which methods are used in the lab.

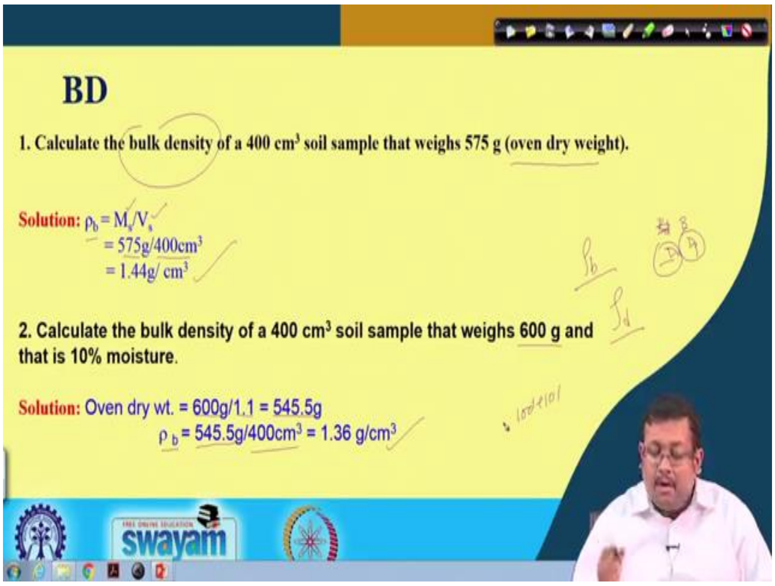
So, these slide you will give you basic overview of different methods of measurement of soil water content. So, we have finished this lecture of measurement of soil water content.

(Refer Slide Time: 20:19)



Let us start a tutorial focusing on different back up a numerical problems and solution for soil bulk density at particle density, soil porosity at soil water content.

(Refer Slide Time: 20:28)



So, let us start with the bulk density calculation. So, you can see the first question is calculate the bulk density of a 400 cubic centimeter soil sample that weighs 575 grams which is it over dry weight.

So, we have to calculate the bulk density. Now one thing I must clear that universally we generally we will we denote this bulk density as rho b and particle density as rho d. So, the so far we were denoting this bulk density and the particle density by B d and sorry D b and D p. So, up to this slide we are denoting this bulk density by this D b and particle density by D p, but from now onl will be using rho b and rho d for determining for indicating the bulk density and particle density.

Now, you can see the solution says that the bulk density here is basically the ratio between mass of solid and the volume; volume of the sorry mass of the soil and the volume of the soil. So, we already know that oven dry weight is 575 grams and the, you know the volume is already given. So, obviously it is 1.44 gram per cc. The second question is calculate the bulk density of a 400 cubic centimeter soil sample that way 600 grams and that is 10 percent moisture.

So, we know that is 600 grams which is already content 10 percent moisture. So, to know the oven dry weight we have to divide this 600 grams with 1.1, 1.1 comes with 100 plus that 10 percent, so 100 percent plus 10 percent, so basically it is 1.1. So, it is ultimately we get the oven dry weight of 545.5 grams and this bulk density is 545.5 we have already calculated the oven dry weight over these total you know bulk volume of the soil.

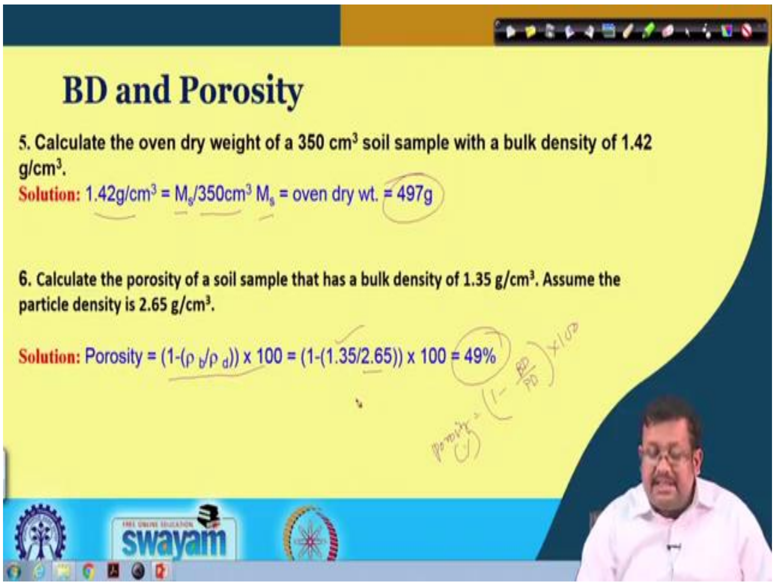
So, we are getting 1.36 gram per cc. So, this is how we can calculate the bulk density if the soil weight is given and the moisture content is also given. So, let us see what is the next problem. So, the third problem says calculate the volume of a soil sample that is 12 percent moisture, weights 650 gram and it has a bulk density of 1.3 gram per cc. So, we know that oven dry weight we know here the moist weight is given that it 650 grams and it contains 12 percent moisture.

So, obviously the oven dry weight will be 650 over 1.12, so it is 580.4 grams. So, this is the oven dry weight and we know that bulk density equal to mass of oven dry weight over the volume. So, from this we can calculate the volume which is 446.4 cubic centimeter. The fourth question is calculate the bulk density of a rectangular soil sample with dimension of 12 centimeter by 6 centimeter, by 4 centimeter that is 15 percent moisture content and weighs 320 grams.

So, the moist weight is given 320 gram, 15 percent moisture content is given. So, let us first calculate the volume of a soil. So, it is a rectangular soil sample. So, the volume will be 12 centimeter into 6 centimeter, it is see 4 centimeter. So, it will be 288 cubic centimeter. Oven dry weight we can calculate from dividing the moist weight by the total moisture content, so it is the 1.15. So, we are getting 272 grams and ultimately we are getting the volume of the soil now we are getting the oven dry weight; obviously, we can calculate now the bulk density which is 0.97 gram per cc.

So, I hope that this calculation you have understood it and so let us go and see what is the next question.

(Refer Slide Time: 25:17)

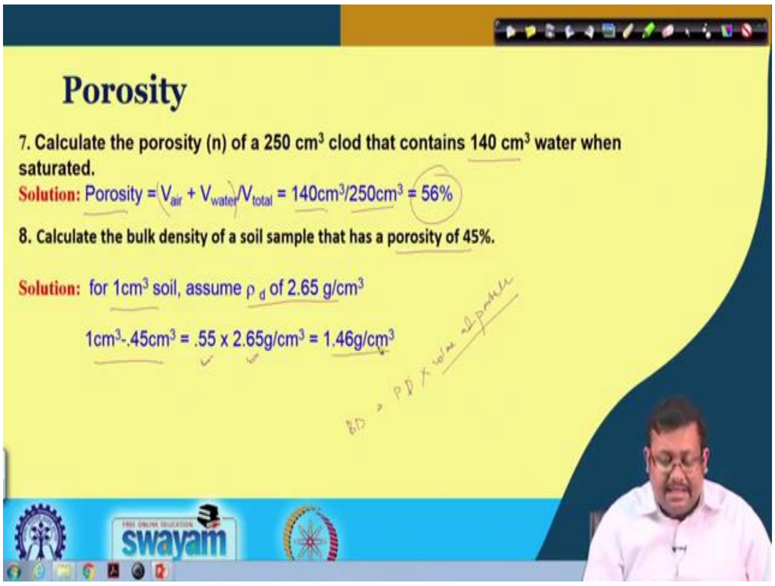


The number 5 fifth problem is calculate the oven dry weight of a 350 cubic centimeter soil sample with a bulk density of 1.42 gram per cc. Now we already know the bulk density is 1.42 gram per cc, we do not know the mass of soil; however, we know the volume of the soil that is 350 cubic centimeter.

So, obviously from that we can calculate the oven dry weight it is 497 grams. The number 6 question is calculate the porosity of soil sample, that has a bulk density of 1.35 gram per cc and assume the particle density at 2.65 gram per cc. Now you already know the formula porosity or porosity is basically porosity is basically 1 minus BD by PD into 100. So, porosity basically we express in terms of percentage.

So, we can see 1 minus BD by you know bulk density by particle density multiplied by 100. So, we know that here the bulk density is 1.35, the average particle density of mineral soils are 2.65 gram per cc, so we can calculate the porosity that is 49 percent. So, now you know how to calculate the porosity from the bulk density and particle density.

(Refer Slide Time: 26:58)



There is another question we know calculate the porosity of a 250 cubic centimeter clod that contents 140 cubic centimeter water when saturated.

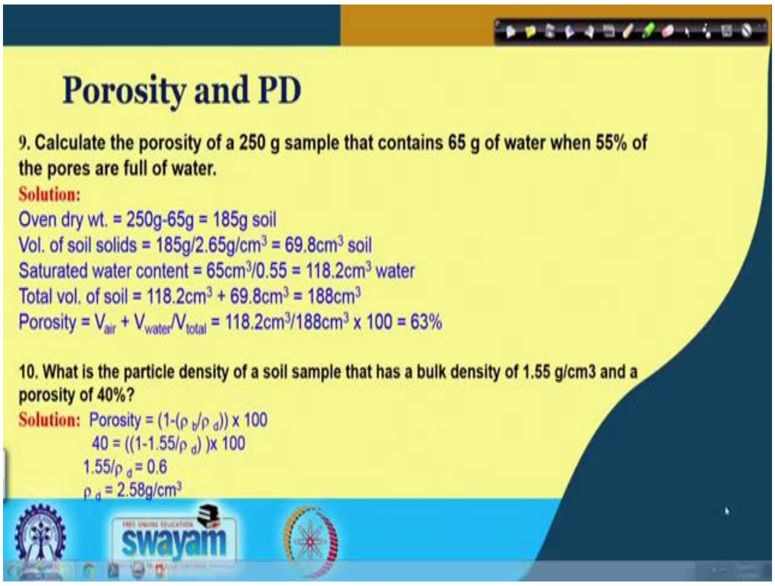
Now, we know that porosity basically can be expressed as a combination of volume of air plus volume of water over volume total volume. Now here we already know that the total volume is 250 cubic centimeter and the volume of air and volume of water is 140 cubic centimeter because, it is says that thus when the soil is saturated, that means all the pore space are filled by water, we are getting 140 cubic centimeter. So, by using this formula, we can easily calculate that is 56 percent.

Number 8 problem is calculate the bulk density of a soil sample that has a porosity of 45 percent. Now here you know porosity is given, bulk density we have to calculate and you know particle density we have to assume that the particle density is 2.65 gram per cc and we will do the all the calculation for 1 cubic centimeter of soil. Now 1 cubic centimeter soil we know that and we are a assuming that particle density of 2.65 gram per cc. So, here porosity here 0.45 percent, so if we subtract 0.45 centimeter from 1 centimeter, we will get 0.55 into 2.65.

So, the bulk density will be here 2.65, so we know that bulk density can be calculated from particle density multiplied by the volume of particles. Now here the volume of particles is solid is 0.55 and we know the bulk particle density is 2.65 gram per cc, so by multiplying it we are getting the bulk density of 1.46 gram per cc.

So, you can now you know now I hope that these are clear to you and you know now you can calculate different problems related to porosity and bulk density.

(Refer Slide Time: 29:41)



Now the last 2 questions are here calculate the porosity of a 250 gram of samples that contains 65 grams of water when 55 percent of the pores are filled with water So, you can see here the oven dry weight is give you know 250 gram minus 65 grams, so it is 185 grams of soil. Volume of soil solutes is the 185 gram over 2.65 gram per cc, so it is 69.8 cubic centimeter.

Saturated water content 65 cubic centimeter over 0.55, so it is 118.2 cubic centimeter of water, total volume of soil; obviously, the volume of water content and volume of soil solids, so the total is 188 cubic centimeter So, porosity will be volume of air plus volume of water over volume of total. We know the volume of air plus volume of water is 118.2 cubic centimeter or that is the saturated water content over the total volume of soil, so it is 188 cubic centimeters. So, ultimately we are getting porosity of 63 cent percent.

Final question what is the particle density of a soil sample that has a bulk density of 1.55 gram per cc and a porosity of 40 percent. So, we know that formula porosity is equal to porosity equal to 1 minus P d by B d sorry 1 minus bulk density over particle density into 100. So, we know the porosity is here 40 and by inputting the bulk density we can calculate the particle density that is 2.58 gram per cc. So, I tried to give you and basic overview of how to calculate different numerical problems regarding the porosity particle density and moisture content.

So, I hope that you have learned something and we will try to cover more numerical problems as the course goes on.

(Refer Slide Time: 31:46)

And I must acknowledge for this numerical problem you know the department of land and water resources of UCA Davis of USA and their class notes I have used for this for setting these a numerical problems. So, thank you and let us meet you know with a new set of lectures for week 4.

Thank you.